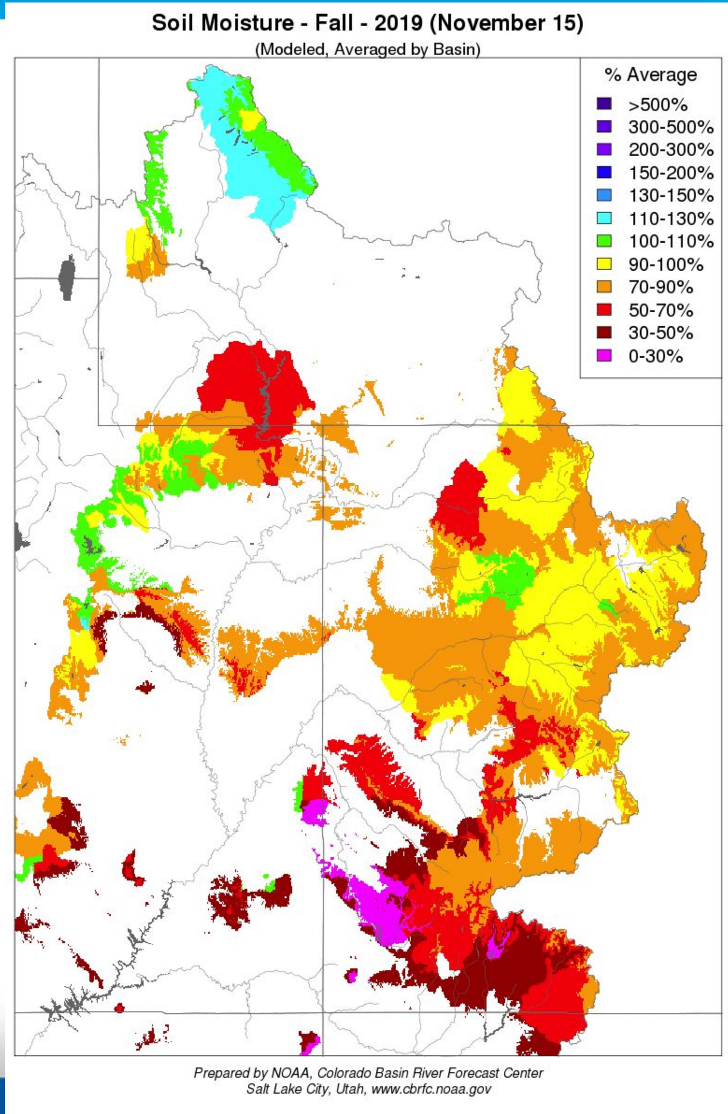
New at the CBRFC for 2020

Overview

- Water Year 2020
- New at the CBRFC
  - Year In Review and Sensitivity Analysis
  - Intervening Flow Update
  - QPF Improvements
  - Lower Basin ENSO Weighting Scheme
  - Incorporating Post-Fire Information
  - National Water Center Backup

Conditions at Start of WY2020

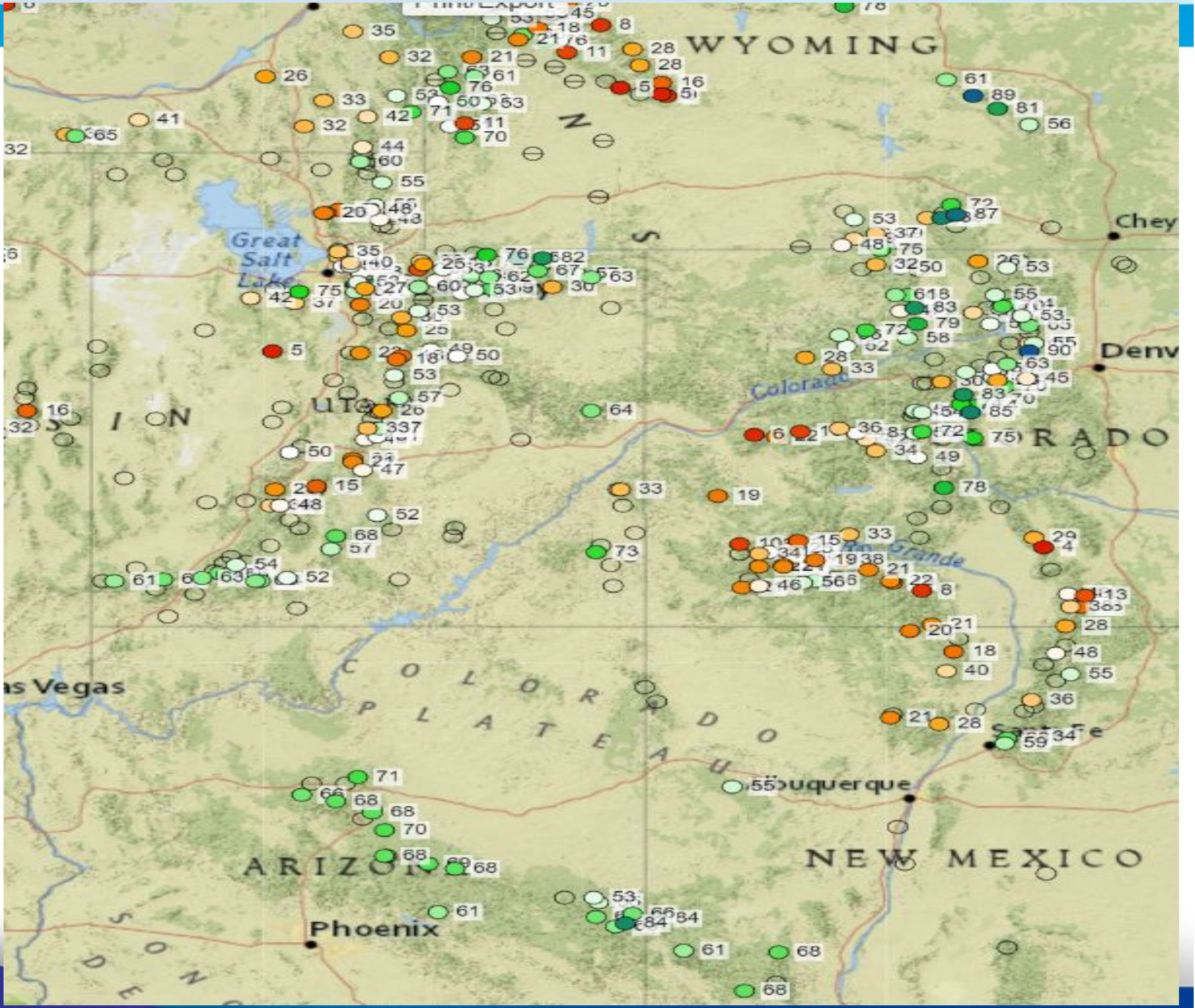
- Very poor monsoon in the summer of 2019
- Model fall soil moisture conditions tended to be below normal in most areas
- ESP forecasts tended to range from 70 - 100%



First Half of WY 2020

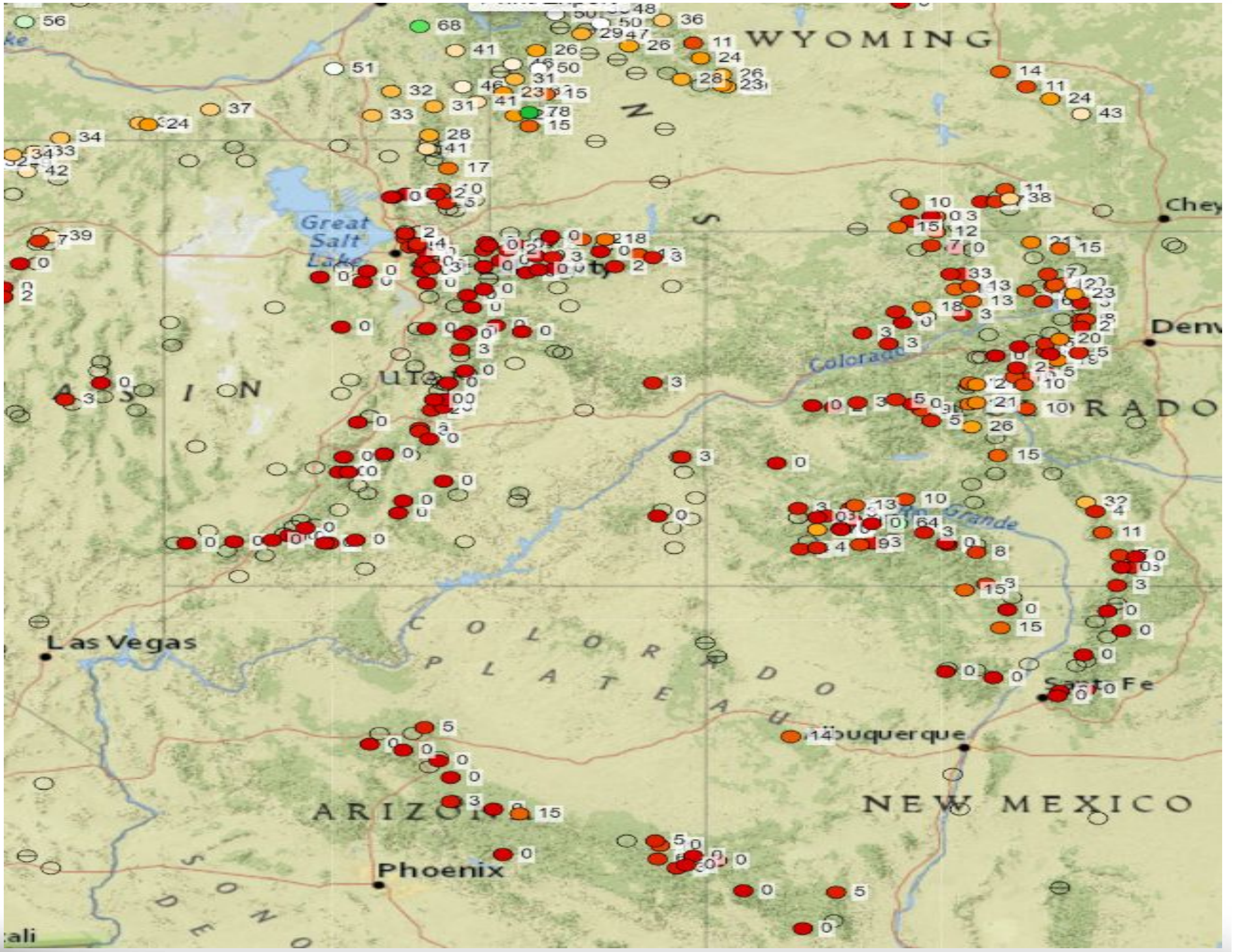
Precip Percentiles from *Oct 1 - March 31*

Somewhat of a mixed bag through the first half of WY 2020, but most locations were near normal. Lower Basin and Upper Colorado headwaters were generally above normal.

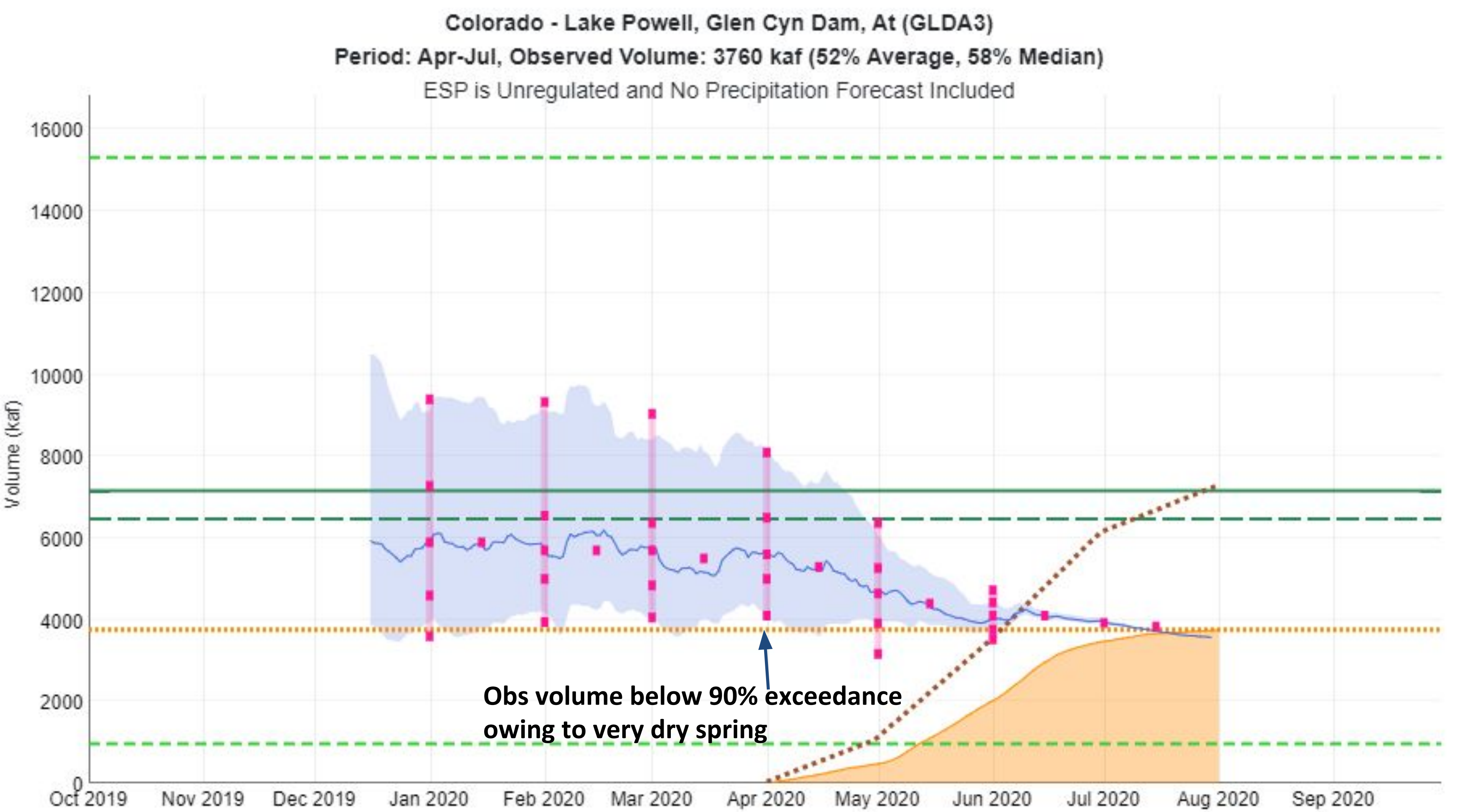


VERY Dry Second Half 2020

Precip Percentiles for *Apr 1 - Sep 30*
Note large portion of Colorado Basin and Great Basin below 15th percentile. Several sites near record lowest (below 5th percentile).

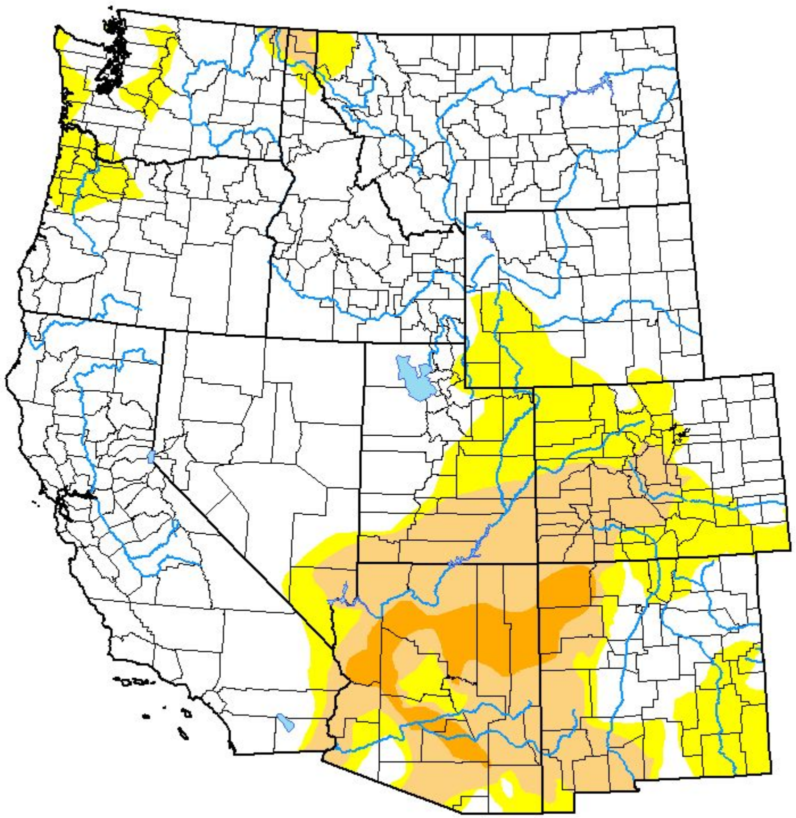


Water Supply at Lake Powell

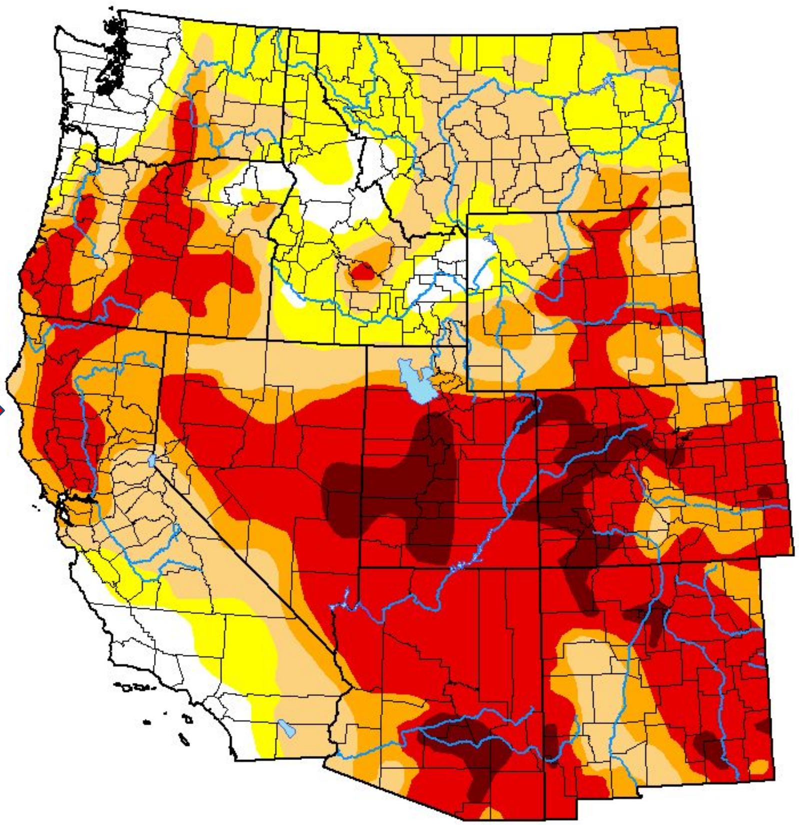


Worsening Drought

October 1, 2019



October 20, 2020



CBRFC Hydrologic Model Sensitivity Analysis

Overview

- Background
- Methodology
- Annual Results
  - Timeframe
  - Parameters

Overview

- Background
  - Colorado River Climate and Hydrology Workgroup
  - Scope of Work
- Methodology
- Annual Results
  - Timeframe
  - Parameters

Scope of Work

- Part 1 asks for CBRFC to provide an annual report summarizing activities
- First annual report released earlier this year and available on CBRFC website

CBRFC Water Year In Review

An Overview of Operational Changes, Improvements, and Investigations over the course of Water Year 2019

April, 2020

National Oceanic and Atmospheric Administration (NOAA)

National Weather Service (NWS)

Colorado Basin River Forecast Center (CBRFC)

Scope of Work

- Year In Review
  - An overview of water supply forecasting conditions and climate
  - Updates to model
  - New products and services
  - Research and Investigations
  - Anything of consequence really!

CBRFC Water Year In Review

An Overview of Operational Changes, Improvements, and Investigations over the course of Water Year 2019

April, 2020

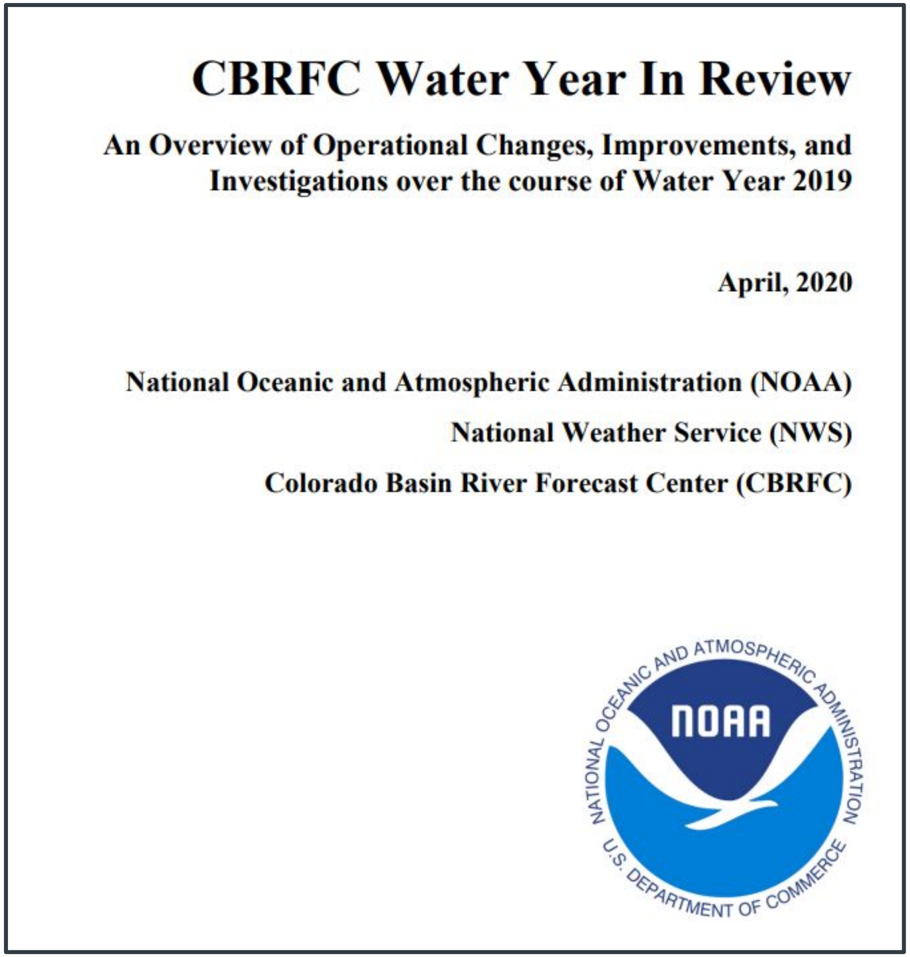
National Oceanic and Atmospheric Administration (NOAA)

National Weather Service (NWS)

Colorado Basin River Forecast Center (CBRFC)

CBRFC Water Year In Review 2020

WY 2020 report likely out by March 2021, if not earlier...



CBRFC Water Year In Review

An Overview of Operational Changes, Improvements, and Investigations over the course of Water Year 2019

April, 2020

National Oceanic and Atmospheric Administration (NOAA)

National Weather Service (NWS)

Colorado Basin River Forecast Center (CBRFC)

Sensitivity Analysis - Scope of Work

- Parameters and site selection
  - Precipitation, Soil Moisture, and Evapotranspiration
    - ±2.5%, ±5.0%, and ±10.0%
  - Temperature
    - ±0.5 ºF, ±1.0 ºF, ±2.0 ºF

Scope of Work

Project: Accuracy Assessment and Sensitivity Analysis of Hydroclimatic Parameters within the Colorado Basin River Forecast Center's (CBRFC) Modeling Framework

Background: The long-term goal of this work is to improve the accuracy of CBRFC's water supply forecast and to achieve this goal, the project is split into two parts.

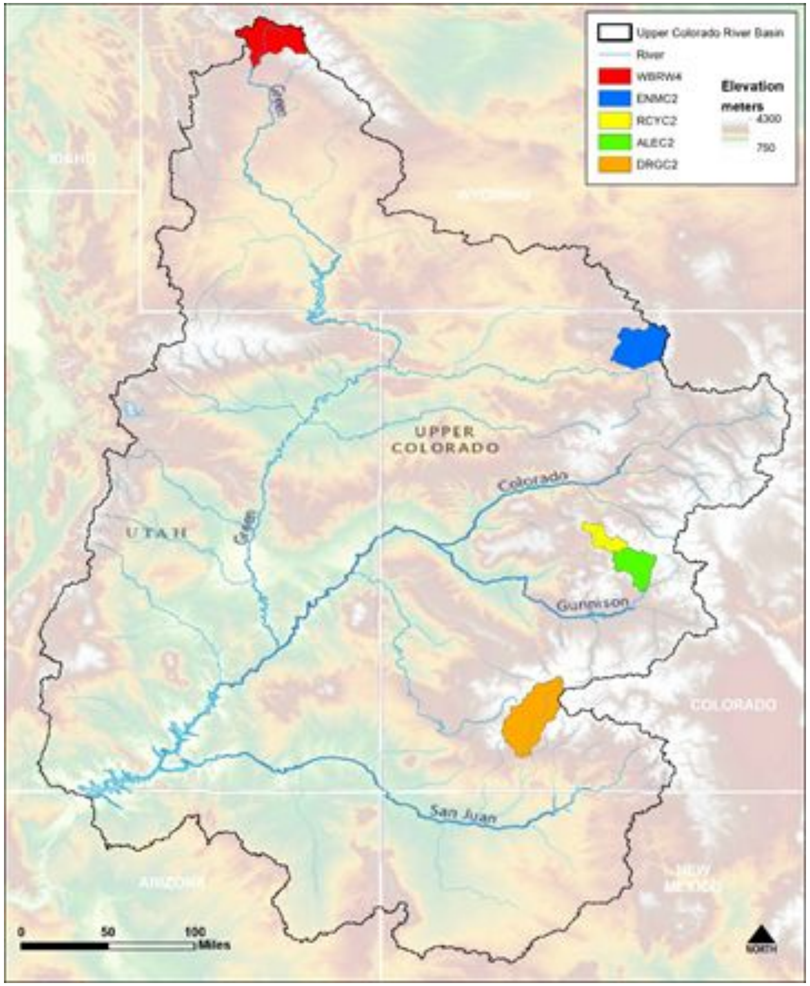
Part 1 – The first part of this project is to document the existing process that CBRFC uses to improve the water supply forecast and to identify opportunities for improving the process or making the process or its products more accessible. CBRFC already uses a robust and on-going accuracy improvement process which includes both inward and outward facing components. For example, CBRFC organizes an annual Water Supply Review/Verification Webinar for stakeholders to describe: what actually occurred; what went well and why; and what can be improved and how. Few stakeholders know, however, that this relatively short webinar is preceded by rigorous internal deliberations.

Part 2 – The second part of this project does not directly investigate the accuracy of the seasonal water supply forecasts per se; rather, it intends to gain an understanding of the magnitude of impact (also referred to as "sensitivity") that changing key components has on water supply forecasts developed using the latest CBRFC methodology and data. This part of the work is referred to as the sensitivity analysis; an evaluation of the effects of changes in input values or assumptions on a model's results. The intent of this work is to lay the foundation for future adjustments to model parameters leading to improvements in model accuracy. For example, knowing the magnitude of impacts and their rank order should help provide direction on which components of the forecast should be examined further. Moreover, this information should help with making investment decisions, i.e., what work may lead to the greatest improvement in accuracy.

In response to stakeholder comments stemming from a drought resiliency meeting, the Bureau of Reclamation (Reclamation) and the CBRFC partnered to identify sources of uncertainty within the water supply forecasts that drive Reclamation's 24-Month Study and its resulting reservoir elevation projections. During initial efforts, sources of uncertainty were identified and presented qualitatively, with little quantitative analysis. Part 2 of this scope is designed to further a portion of Reclamation's and CBRFC's past effort by quantitatively assessing the sensitivity of uncertainties associated with the water supply forecast specifically, which fall into three categories: model parameters, initial model conditions, and model forcings.

Scope of Work

- Site Selection
  - Green River at Warren Bridge (WBRW4)
  - Elk River near Milner (ENMC2)
  - Crystal River near Redstone (RCYC2)
  - East River at Almont (ALEC2)
  - Gunnison at Durango (DRGC2)
  - ~~GLDA3 (Lake Powell)~~
  - OAWU1* - (Weber at Oakley in Great Basin)
- Sites have minimal regulation and diversions, so easier to isolate impacts



Methodology

- 1981-2015 traces for each parameter at each site
  - 1981 not considered for analysis (used as a spin-up year)
  - 816 scenarios (4 parameters X 6 perturbations X 34 years) for each site
- There are equivalent figures for all sites, all years, and all timeframes
- All data is available on our website

Methodology

Not quite apples to apples….

Temperature	Gage-derived	Perturbed by ^{o}F	6-hourly MAT values
Precipitation	Gage-derived	Perturbed by %	6-hourly MAP values
Soil Moisture	Developed during calibration	Perturbed by %	October 1st value
Evapotranspiration	Developed during calibration	Perturbed by %	Monthly, static, coefficients


Red delicious

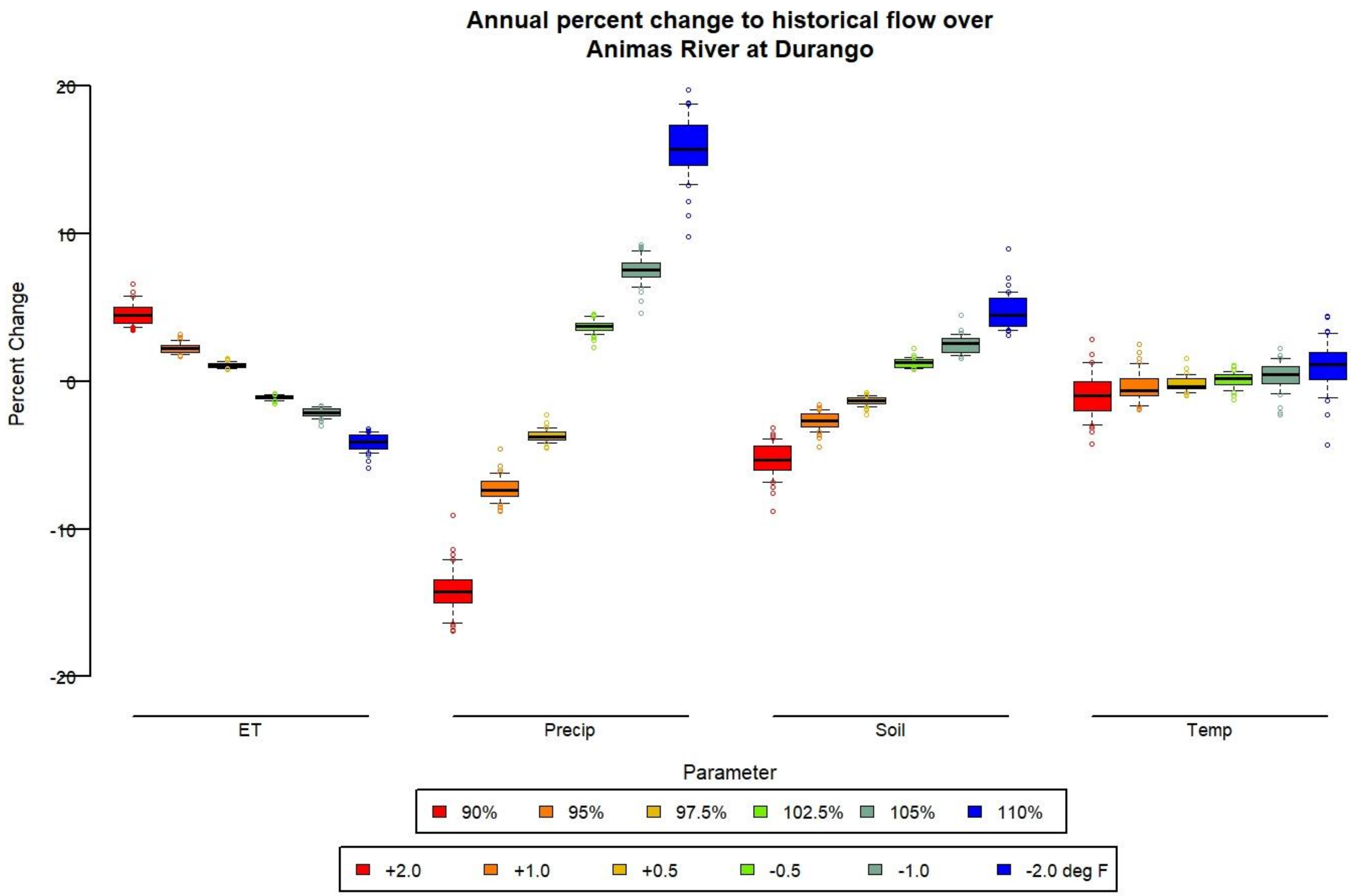

McIntosh

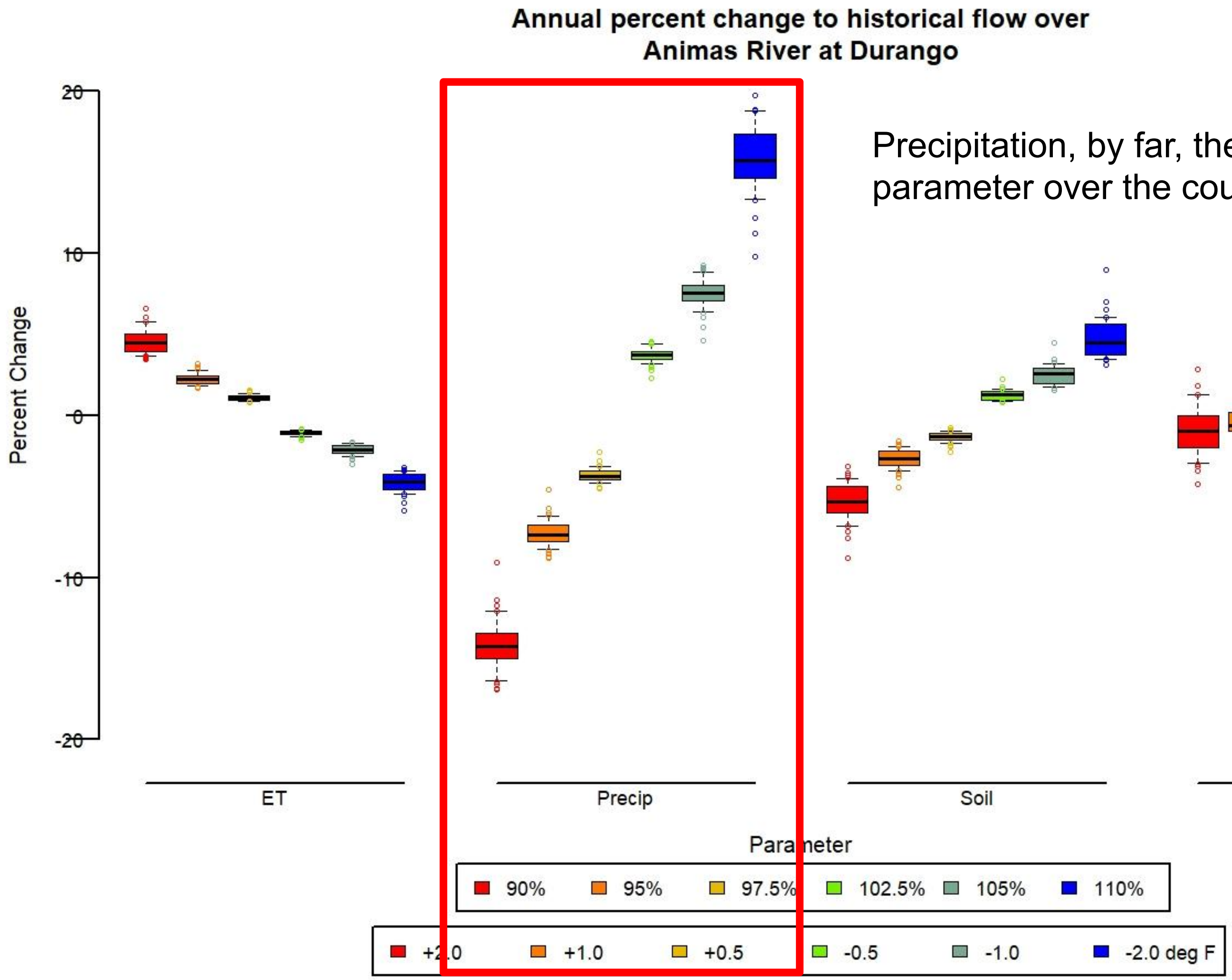

Rhode Island greening


Grimes golden

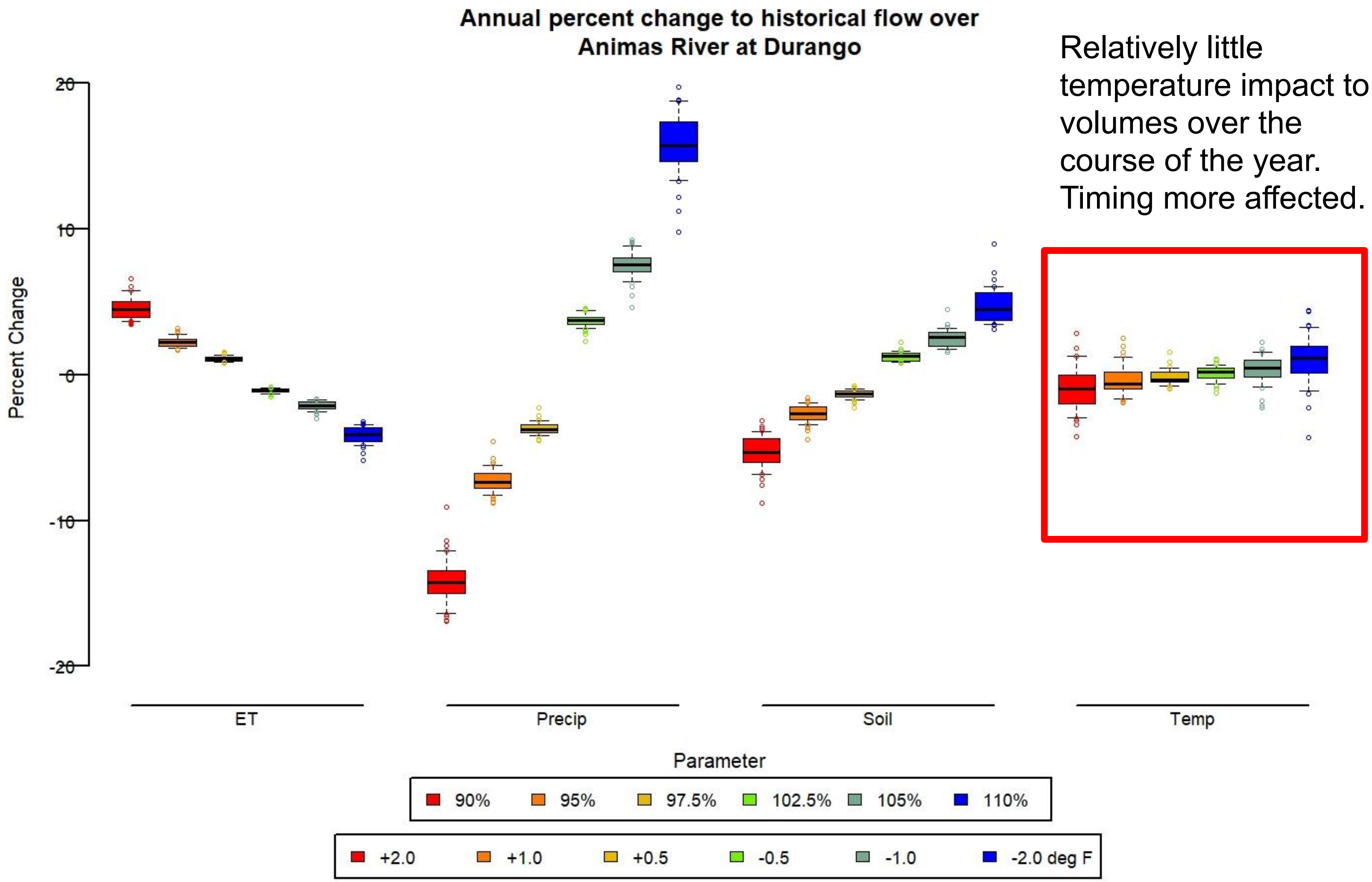
Annual Results

- Precipitation most impactful
  - 1.5% increase per 1% increase in precipitation
- Evapotranspiration and Soil Moisture next most impactful parameters
  - 0.5% increase per 1% increase in soil moisture
  - 0.4% decrease per 1% increase in ET
- Temperature least impactful over course of a year
  - 0.35% decrease per 1 ^{o}F increase in temperature
  - Other parameters are not dependent on temperature


Annual percent change to historical flow over
Animas River at Durango
Percent Change
20
10
0
-10
-20
ET
Precip
Soil
Temp
Parameter
90%
95%
97.5%
102.5%
105%
110%
+2.0
+1.0
+0.5
-0.5
-1.0
-2.0 deg F



Precipitation, by far, the most impactful parameter over the course of the year.

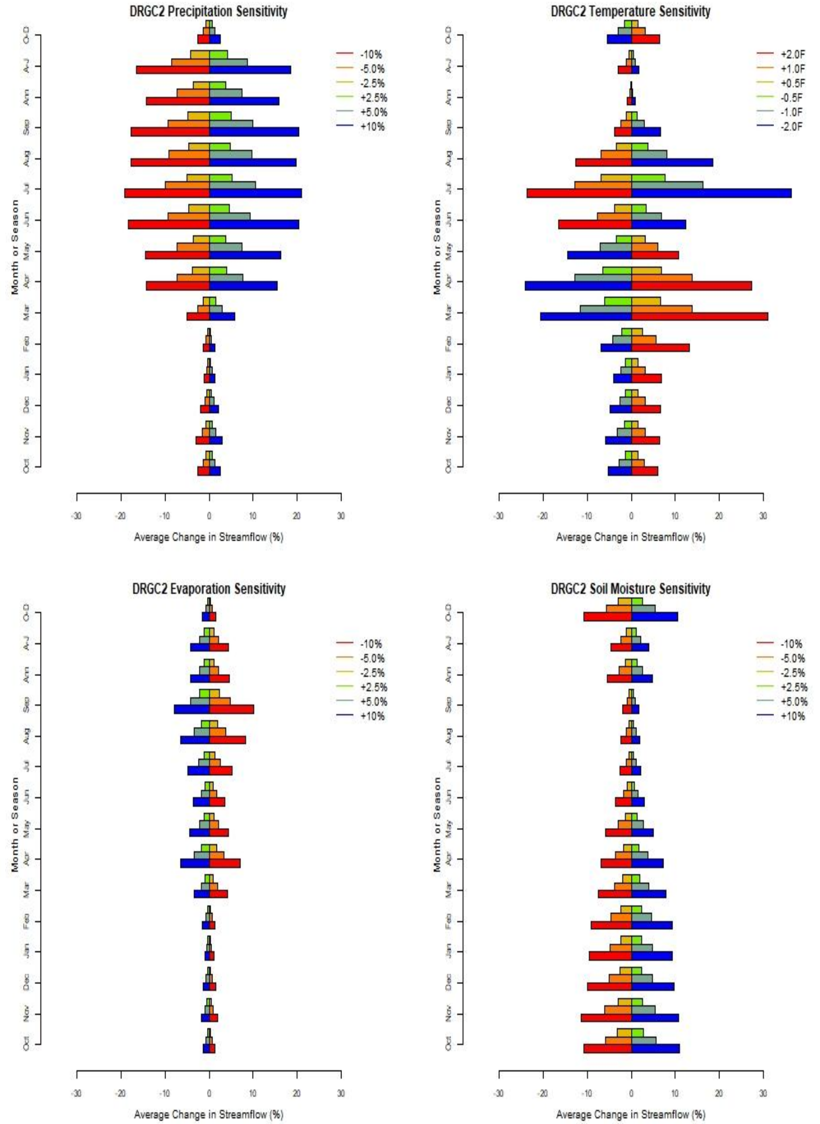


Relatively little temperature impact to volumes over the course of the year. Timing more affected.

The Take Away

- The Colorado Basin River Forecast Center conducted a sensitivity analysis investigating how changes to temperature, precipitation, evapotranspiration, and soil moisture affected streamflow volumes
  - Annual, Apr - Jul, Oct - Dec, and monthly timeframes considered
  - Not a climate change study
- Precipitation typically the most impactful parameter
  - Temperature impacts are greatest in Fall/Winter and timing of runoff
  - Soil Moisture and Evapotranspiration can also be significant at times

NOT A CLIMATE CHANGE STUDY



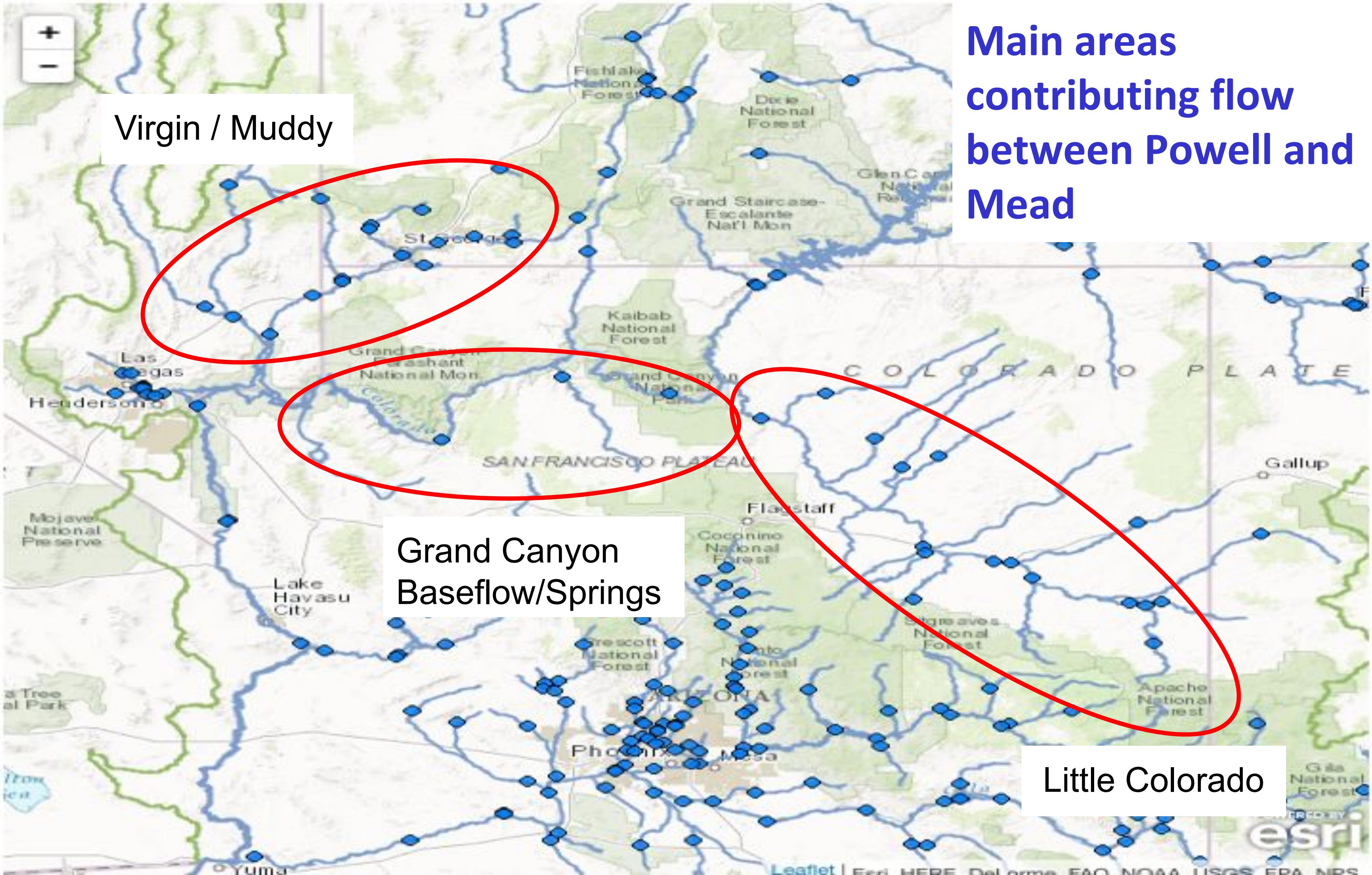
Where to find these reports

Year In Review - https://www.cbrfc.noaa.gov/present/yir_2019.pdf

Sensitivity Analysis - https://www.cbrfc.noaa.gov/report/CBRFC_Model_Sensitivity_Analysis_2020.pdf

Supplemental Info - https://www.cbrfc.noaa.gov/report/Sensitivity_Analysis_Supplemental_Information.zip

Intervening Flow (LML) Update



Main areas contributing flow between Powell and Mead

Motivation

- Previously only had ~5 years of verification of ESP method, and only verified the first three months (lead months 1-3)
- Now we have a 30 year (1981-2010) ESP reforecast dataset that goes out a year (lead months 1-12)

- Would like to answer the question:

1) How does the ESP method verify compared to just using Climo? More specifically, how does the verification vary by the month of issuance and by lead time?

Methodology

Forecasting Methods:

- CBRFC ESP method will be referred to as **RFC**
- 1981-2010 CBRFC Climo will be referred to as **Climo**
- The average of RFC and Climo will be referred to as **Blend**
- Verified against the CBRFC LML observation.

Verification Stats:

- *Monthly* Mean Absolute Error (**MAE**) and running 3-month *Seasonal* MAE

Best Method by Season

Here is a table that shows what forecast method is superior as a function of issuance month and lead time. *Seasonal* (3-month running total volume) verification is considered here.

InitMonth	ond	ndj	djf	jfm	fma	mam	amj	mjj	jja	jas	aso	son	ond	ndj	djf	jfm	fma	mam	amj	mjj	jja
oct	Blend	Blend	Blend	Blend	Climo	Blend	Blend	Climo	Climo	Climo											
nov		Blend	Blend	Blend	Blend	Blend	Blend	Climo	Climo	Climo	Climo										
dec			Blend	Blend	Blend	Blend	Blend	Blend	Climo	Climo	Climo	Blend									
jan				Blend	RFC	RFC	RFC	Blend	Climo	Climo	Climo	Blend	Blend								
feb					RFC	RFC	RFC	RFC	Climo	Climo	Climo	Climo	Blend	Blend							
mar						Blend	RFC	Blend	Climo	Climo	Climo	Climo	Blend	Blend	Blend						
apr							RFC	Blend	Climo	Climo	Climo	Climo	Blend	Blend	Blend	Blend					
may								RFC	Climo	Climo	Climo	Climo	Blend	Blend	Blend	Blend	Blend				
jun									Climo	Climo	Climo	Climo	Blend	Blend	Blend	Blend	Blend	Blend			
jul										Climo	Climo	Climo	Blend	Blend	Blend	Blend	Blend	Blend	Blend		
aug											Climo	Climo	Blend	Blend	Blend	Blend	Blend	Blend	Blend	Climo	
sep												Climo	Blend	Blend	Blend	Blend	Blend	Blend	Blend	Climo	Climo

One can argue that outside of the summer (Climo) and portions of the late winter/spring (RFC), the **Blend** is tough to beat. The verification I have done over the past six water years (WY 15-20) also shows this.

What’s Next?

- The largest potential for further improvement could be from incorporating ENSO into the prediction for winter-spring LML. For example, does weighting the ESP traces based on the ENSO state work for the intervening flow region? This is an avenue for further research.

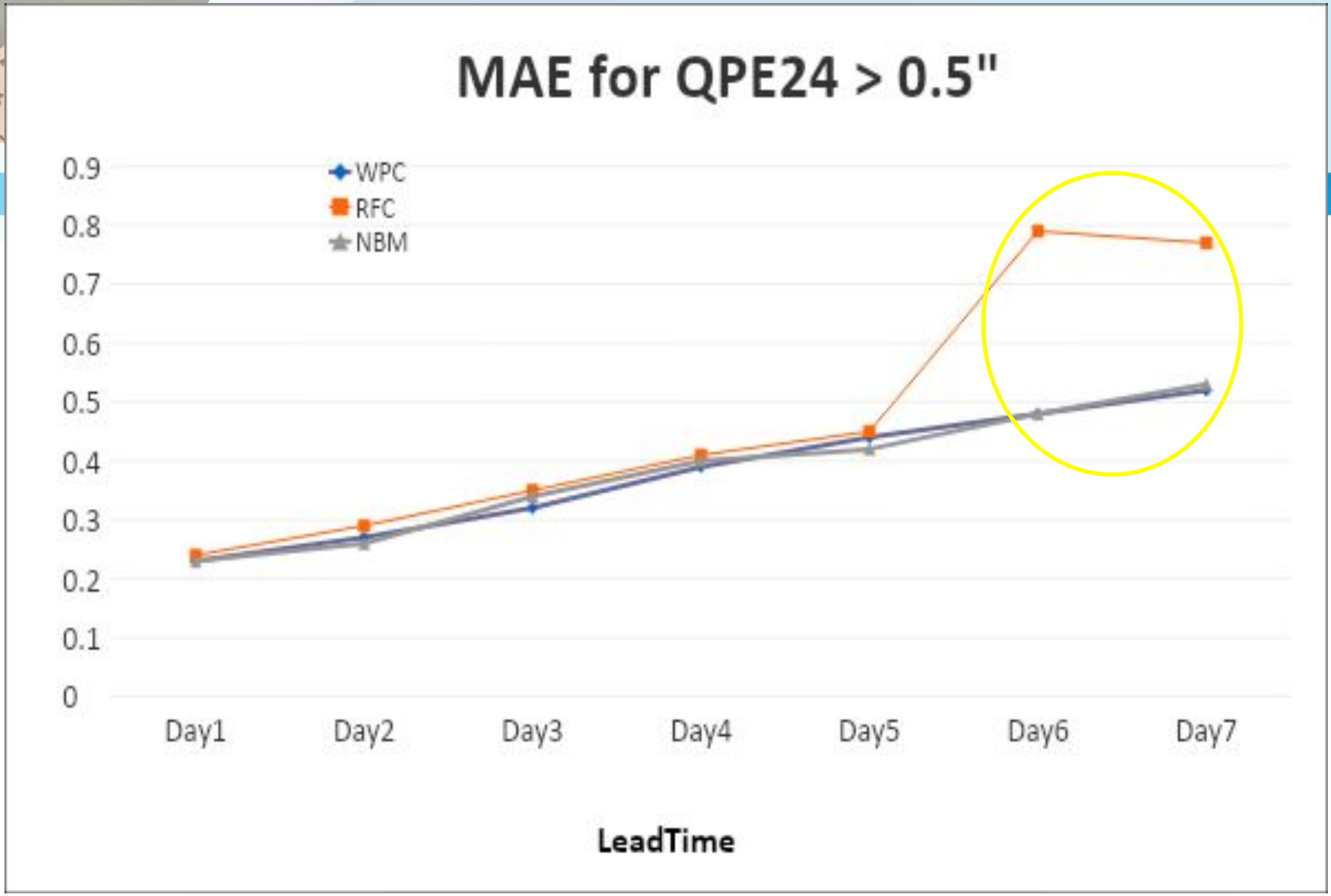
- We have provided Reclamation with the 1981-2010 reforecast dataset and they are currently performing their own research. Reclamation will now provide an update.

QPF Improvements

QPF Verification Methods

- Verification since July 2018.
- **QPF24** – 24 hourly QPF (12-12Z)
- Models included:
  WPC, **NBM**, *AND*
  RFC (WPC on Days 1-5, QPF=0 on Days 6-7)
- Considered headwater zones over the *Upper Basin* and *Great Basins*

- *Question*: How does the RFC forecast verify compared to WPC/NBM, with specific attention on Days 6/7?



- WPC performance is similar to NBM over all lead times.
- By forecasting QPF=0 on Days 6/7 and not using WPC, *overall* we are missing out (note big jump in error). How does this vary by season?

MONTHLY BREAKDOWN

WPC-RFC MAE Diff (Day 7)

QPE Range	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
qpe=0	0.01	0.01	0.02	0.02	0.04	0.08	0.04	0.03	0.02	0.03	0.03	0.02
0<qpe<=0.50	-0.02	-0.04	-0.03	-0.05	0	-0.03	-0.02	-0.02	-0.01	0.03	0.02	0.01
0.50<qpe<=0.85	-0.28	-0.27	-0.26	-0.17	-0.21	-0.39	-0.17	-0.29	-0.04	-0.08	-0.15	-0.19
0.85<qpe<=1.25	-0.2	-0.37	-0.14	-0.29	-0.29	-0.55	-0.24	-0.32	-0.03	N/A	-0.1	-0.09
1.25<qpe<=1.75	-0.25	-0.94	-0.41	-0.35	-0.52	-0.66	-0.33	-0.47	-0.06	N/A	N/A	-0.5
qpe>1.75	N/A	N/A	N/A	-0.38	-0.65	-0.67	-0.27	N/A	-0.11	N/A	N/A	-0.39
qpe>=0.50	-0.26	-0.33	-0.25	-0.22	-0.27	-0.45	-0.2	-0.3	-0.04	-0.09	-0.14	-0.2

- When no precip is observed (QPE=0), WPC is slightly worse (but only a few hundredths). However, note that WPC is overwhelming better when precip is observed.
- ***More importantly***, at the heaviest events, WPC's outperformance grows in magnitude (i.e. diff becomes more negative).

SUMMARY

- *The weight of the evidence indicates that using WPC for Days 6/7 is more accurate than forecasting a QPF=0. This is especially true during the wet months (Oct-May).*

Changes as of fall 2020:

1) Switch to using **WPC for Days 6/7 QPF** in the *Upper Basin and Great Basin*, similar to the Lower Basin. This impacts our daily operational model. We still use QPF=0 for Days 8-10.

2) Use **seven** days of QPF/QTF in our ESP run that incorporates QPF (**ESP w/QPF**). Previously we were only using five days.

Lower Basin ENSO Weighting Scheme

OVERALL GOAL

Develop a statistical weighting scheme for Lower Basin water supply basins (Gila, Salt, Verde, Virgin) using teleconnection indices that optimizes skill increase over our current ESP method of equally weighting (EW) every trace.

- Scheme must be *objective* and be applied *operationally* in an easy manner. This means that it will initially be based on **observed** teleconnection indices prior to the runoff period.
- Will rely on reforecasts over the 1981-2020 period to optimize the weighting parameters.

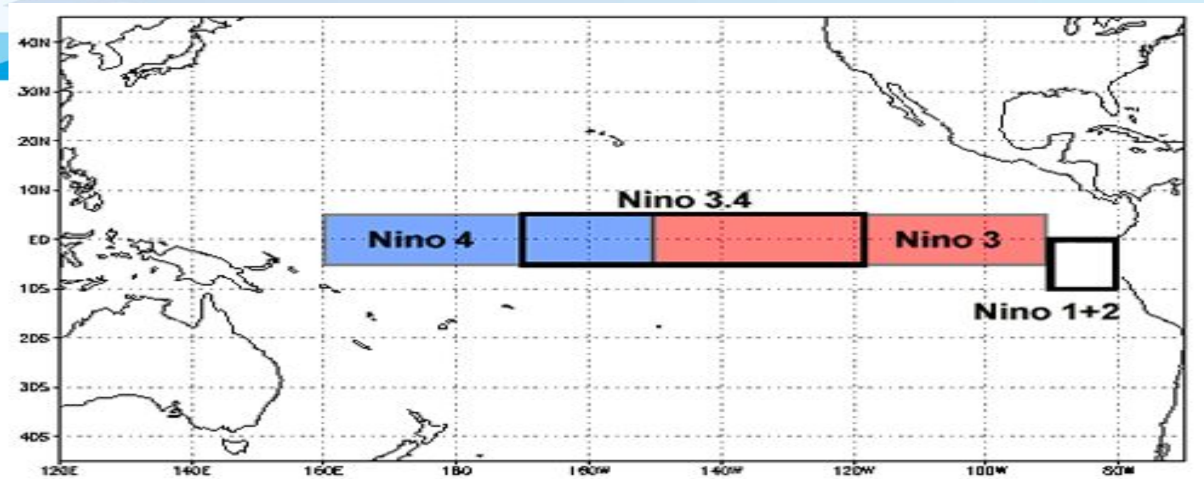
Question: What is the sweet spot (number of nearest neighbors) that optimizes skill increase compared to equal weighting (RPSS)?

CORRELATIONS
Index vs. JanMay Runoff

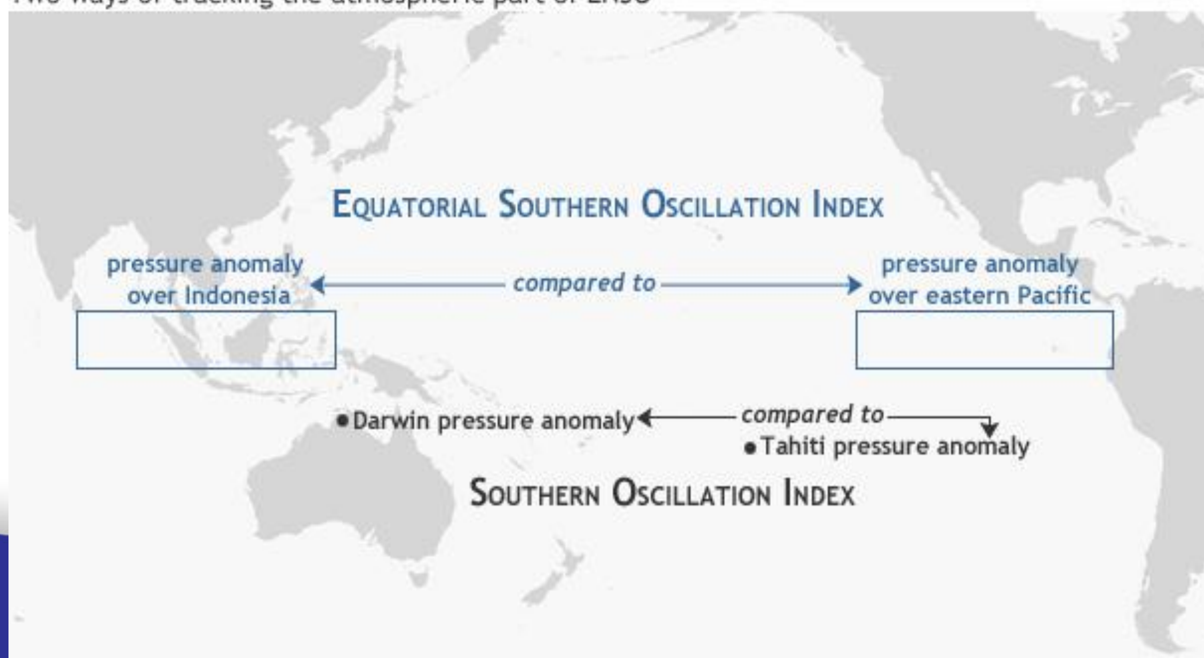
	GLHA3 *Gila*	SLRA3 *Salt*	VDTA3 *Verde*	VIRU1 *Virgin*
EQSOI	-0.42 Nov	-0.49 Nov	-0.44 Nov	-0.35 Nov
EQSOI_3mean	-0.39 OND	-0.45 OND	-0.42 OND	-0.29 SON
MEI	0.44 ND	0.46 ND	0.45 ND	0.29 ND
NAO	0.36 Aug	0.34 Aug	0.28 Nov	0.2 Aug
NINO12_anomaly	0.3 Dec	0.32 Dec	0.31 Dec	0.33 Dec
NINO3_anomaly	0.3 Dec	0.35 Dec	0.34 Dec	0.29 Dec
NINO34_anomaly	0.34 Dec	0.37 Dec	0.37 Dec	0.27 Dec
NINO4_anomaly	0.34 Jul	0.33 Dec	0.34 Dec	0.26 Dec
ONI	0.33 MJJ	0.34 OND	0.32 OND	0.23 OND
PNA	-0.24 Dec	-0.31 Dec	-0.24 Dec	-0.28 Dec
PDO	0.29 Oct	0.29 Sep	0.25 Sep	0.23 Sep
SOI	-0.42 Nov	-0.45 Nov	-0.43 Nov	-0.34 Nov
SOI_standardized	-0.47 Oct	-0.46 Oct	-0.44 Nov	-0.34 Nov
SOI_standardized_3mean	-0.47 OND	-0.48 OND	-0.45 OND	-0.29 OND
TNI	-0.18 DJF	-0.16 DJF	-0.22 DJF	-0.27 DJF

Correlation coefficient - r

ENSO Indices

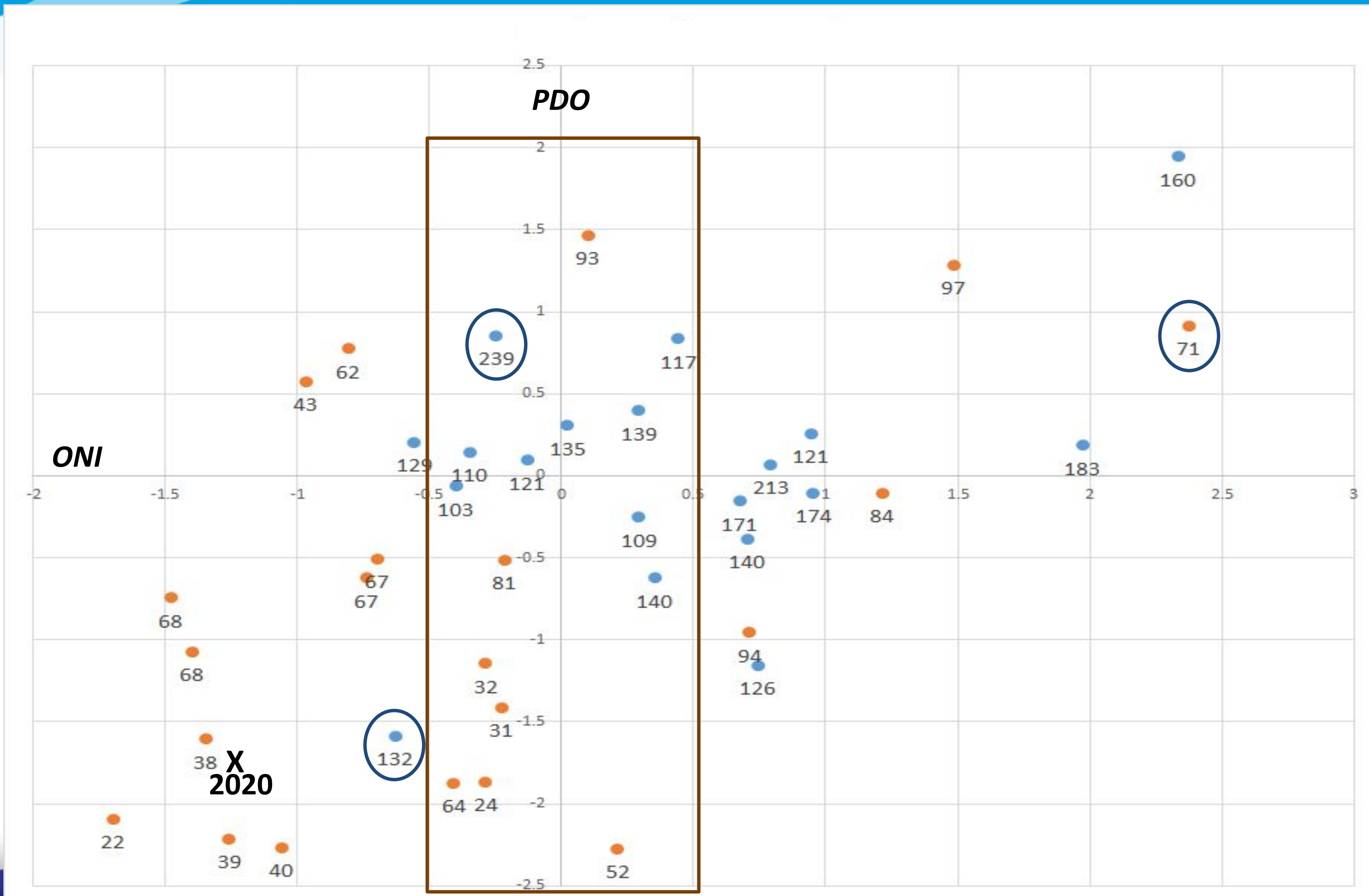


Two ways of tracking the atmospheric part of ENSO



Does Pairing Two Indices Improve Things?

ONI/PDO and JanMay Precip (AZ_Div7)



Can We Improve on Equal Weighting?

- The goal is to shift the ESP distribution if there is a *consistent* teleconnection signal. This will likely be possible for the Lower Basin, and maybe even for *some* Upper Basin areas. The Upper Basin has yet to be examined extensively.

- There is no holy grail for weighting ESP using teleconnections. Outlier years will always be an issue. However, if we improve upon equal weighting *overall* (say in 10 of 12 La Nina years), then I consider that a success.

Incorporating Post-Fire Information

CBRFC 2020 Fire Hydrology Development Work

- CBRFC Post Fire DSS Role:
  - Provide hydrologic support to Weather Forecast Offices (WFOs) in first 24 hours of forecast period
    - CBRFC Lower Colorado basins are forced with 1-hr precipitation during first 24 hours of model run
- Python/GIS Post Fire Tool Development
- Hydrologic Model Considerations
- Bush Fire (Arizona) / Sycamore Creek (SYCA3) Example

BAER & BARC

- BAER (Burned Area Emergency Response)
  - Within 7 days of fire containment, the BAER Imagery Support Program provides satellite images, burn area severity classifications, and other critical data to BAER teams. One of the team's first tasks in the field is to create a soil burn severity map using BARC data provided by the BAER Imagery Support Program.
- BARC (Burned Area Reflectance Classification)
  - BARC is a satellite-derived data layer of post-fire vegetation condition. The BARC has four classes: high, moderate, low, and unburned. This product is used as an input to the soil burn severity map produced by the Burned Area Emergency Response (BAER) teams.

CBRFC Fire Tool Development

- Python/GIS Fire Tool Inputs:
  - BARC geo tiff or .shp file of burn area / severity
  - CBRFC basin elevation zone .shp file

- Outputs
  - Maps (basin scale, forecast group scale)
  - Plots (broken down by CBRFC basin elevation zone)
    - Fire size (mi^2)
    - % of elevation zone burned and burn severity
  - Tables
    - Tabular data of plots
  - Shapefiles of burn areas

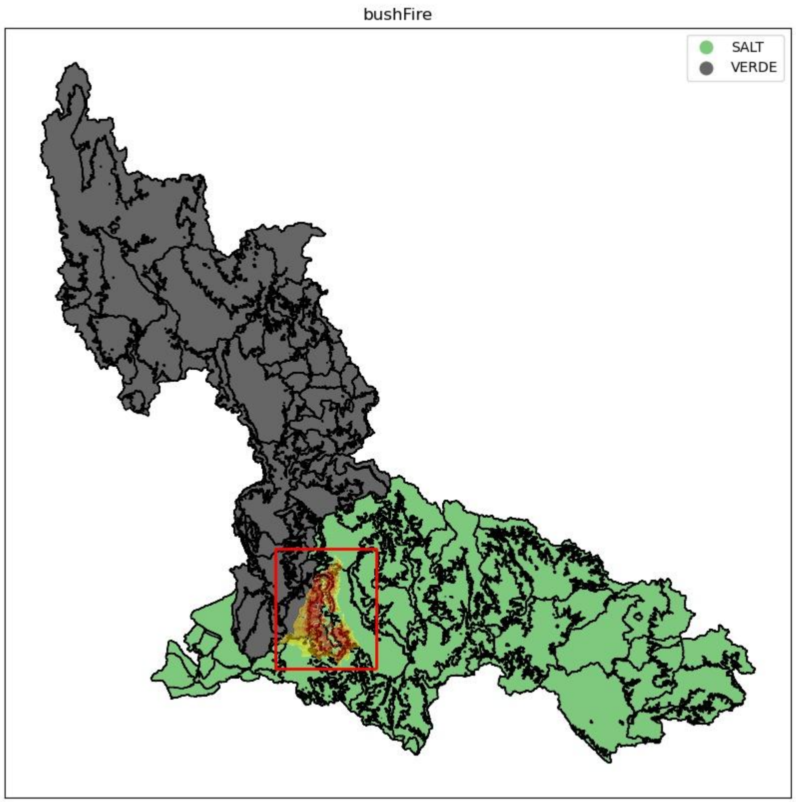
- Future Development
  - Determine type of vegetation burned (forest, shrub, etc.)

Hydrologic Model Considerations & Initial Burn Thresholds

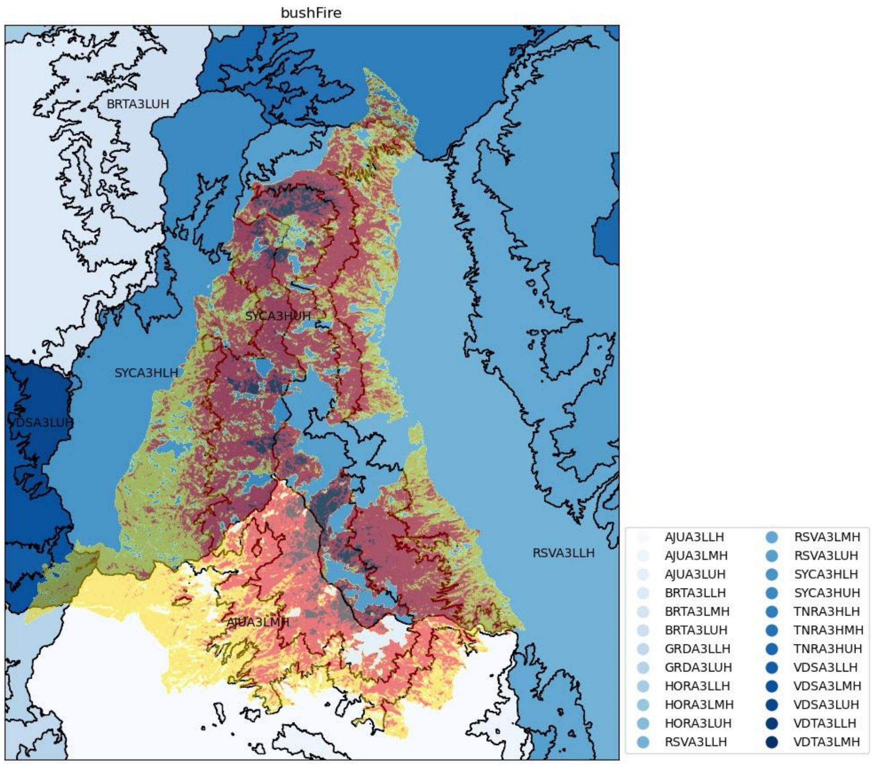
- CBRFC basin elevation zone:
  - >50% burned
    - Adjust SAC-SMA model parameters for basin elevation zone
  - 25-50% burned
    - Define & configure new burn polygon hydrologic model area using fire tool output .shp file
- Continuously evaluate hydrologic model performance during observed precip on burn events
  - Arizona hydrology is challenging to begin with:
    - Losses to soils
    - Reliability of observed streamflow data (shifty channels/ratings)
- Maintenance
  - Documentation
  - Model Configuration

Example: 2020 Bush Fire (Arizona) Sycamore Creek (SYCA3) Basin

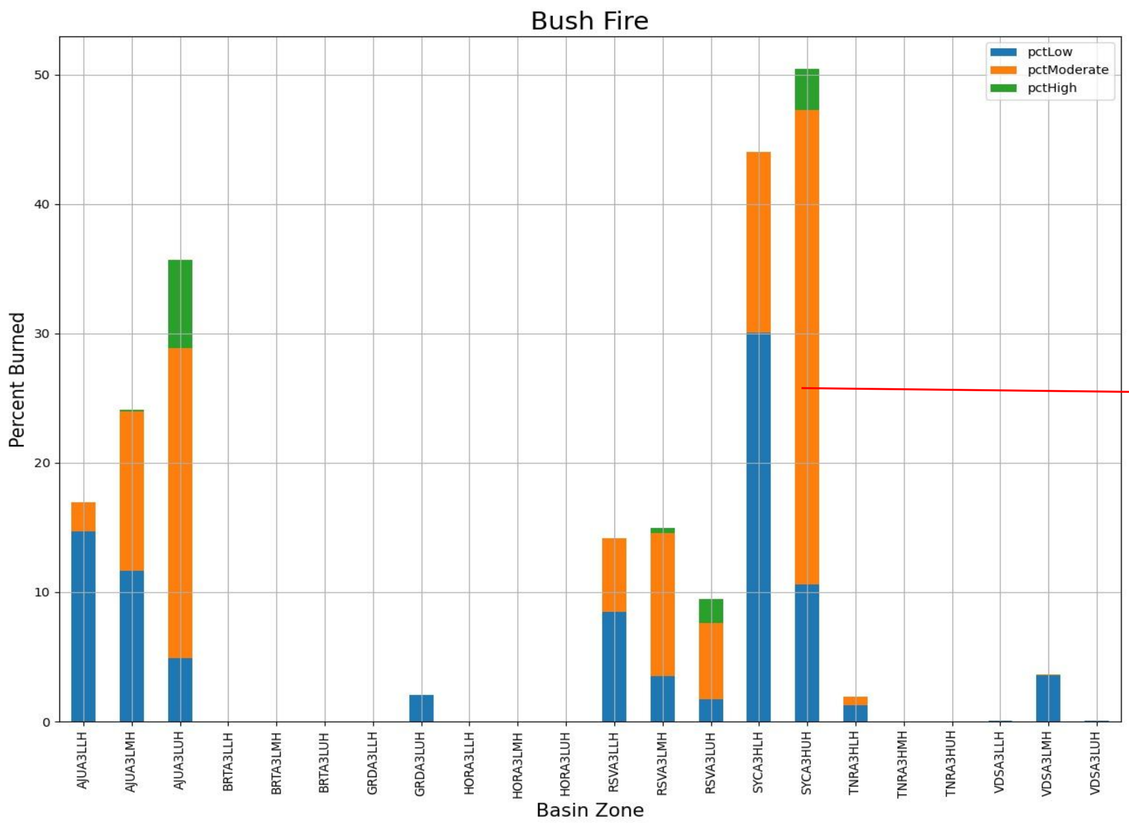
Forecast Group Output Map



Basin Scale Output Map



Example: 2020 Bush Fire (Arizona) Sycamore Creek (SYCA3) Basin



SYCA3 upper elevation zone is >50% burned

Adjust SAC-SMA model parameters

SAC-SMA Model Parameter Adjustments

- **UZTWM**: upper soil zone layer tension water capacity (bucket size), units = mm
  - Parameter indicates the amount of rain that must fall after a long dry period before any runoff is produced
- **UZFWM**: upper soil zone layer free water capacity (bucket size), units = mm
  - Primary function is to control when surface runoff occurs
  - Surface runoff can only occur when the intensity rate of rainfall or rain+melt is sufficient to fill the upper zone free water storage

SYCA3 Upper Elevation Zone Model Adjustments

Parameter	Pre Fire	Post Fire
UZTWM	30	10
UZFWM	40	10

Anderson SAC-SMA Calibration Manual

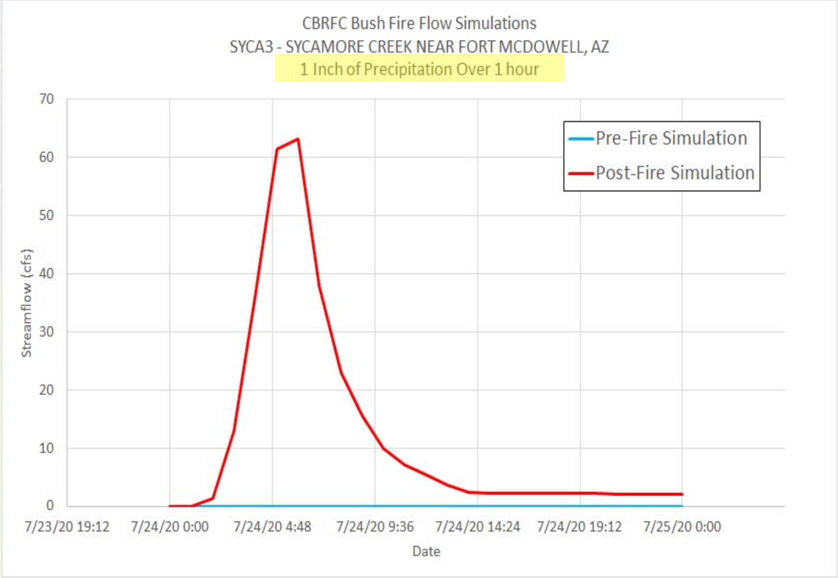
Table 7-5-1. Guidelines for initial estimate of UZFWM.

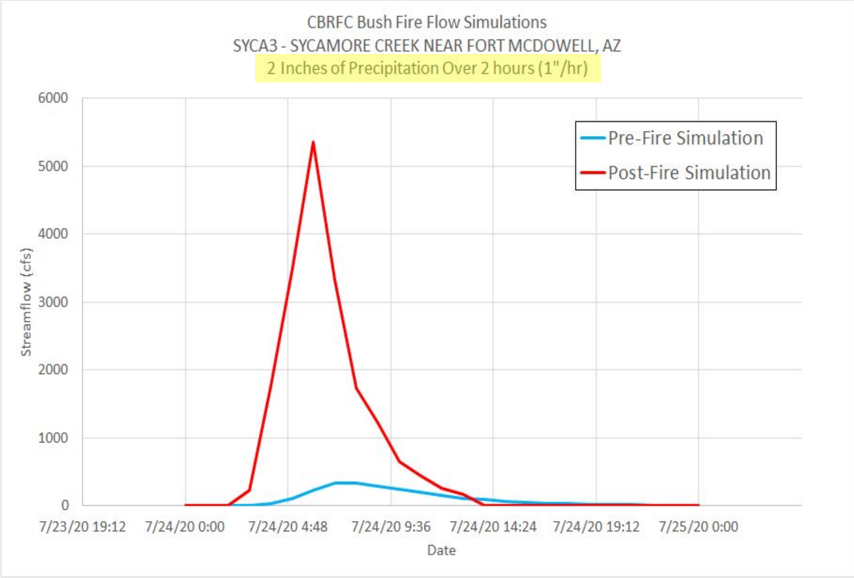
Frequency of Surface Runoff	Suggested Initial Value of UZFWM
Every moderate to heavy rainfall event (i.e. very frequently)	10 - 20 mm
Every large rainfall event	15 - 30 mm
Only during the largest flood events	30 - 60 mm (upper end of range for very wet regions)
Never or only during a record flood event	40 - 100 mm (upper end of range for very wet regions)

Sycamore Creek (SYCA3)
What-If Model Flow Simulations

CBRFC Pre vs. Post Fire Simulation Analysis:

- 1” precipitation in 1 hour
- 2“ precipitation in 2 hours (1”/hr)





CBRFC Fire Development Summary & Final Thoughts

- Developed tool to analyze fire burn areas/severity in relation to CBRFC modeled basins/elevation zones
- Developed initial burn thresholds/modeling approaches
- Continue to evaluate observed precip on burn area runoff events
  - Are initial burn thresholds / modeling approaches reasonable?
- Build & maintain historical fire/burn database

- The process hasn't been tested by a high impact event
- Only focus has been non-water supply forecast points (Arizona)
- What priority/amount of development time should CBRFC be investing in fire hydrology?
- Continue to collaborate & share tools/event analyses with other RFCs

- QUESTIONS?

National Water Center Backup

NWC Backup

- Now have very limited backup capabilities
- Text product only
- Short term 10 day forecast only, ie no water supply forecast
- Limited data inputs and not similar to current operations
- Plans are for capabilities to be expanded